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# **Pilot Fatigue and Circadian Desynchronosis**

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Report of a Workshop held in San Francisco, California  
on August 26-28, 1980



National Aeronautics and  
Space Administration

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## INTRODUCTION

The workshop on "Pilot Fatigue and Circadian Desynchronosis was sponsored by NASA and was held at San Francisco, CA on August 26-28, 1980. The purpose of the workshop was to assist NASA in responding to a Congressional request\* that NASA determine whether "the circadian rhythm phenomenon, also called jet lag" is of concern, "and either decide, if in fact: one, there is any valid reason to look at it; and two, what agency should be doing it."

In response to this request NASA coordinated with the FAA and other appropriate organizations and concluded that more information was needed before a determination could be made as to whether a research program is warranted for circadian desynchronosis, and if so, what it should consist of.

To assist NASA in making a determination and in pinpointing the numerous issues involved, a group of experts was invited to participate in a workshop. The program was organized by Dr. Joseph C. Sharp, Deputy Director of Life Sciences (Chairman); Dr. Alan Chambers, Chief of the Man-Vehicle Systems Research Division, and Dr. Charles M. Winget of the Biomedical Research Division, all of NASA's Ames Research Center.

The workshop participants, in their view, formed a unique group: there were representatives from the scientific community including university, military, and other federal agency scientists; and the aviation community, including airline pilots and representatives of airline management. The list of participants is given as Appendix A.

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\*Hearings before the Subcommittee on Transportation, Aviation and Communications of the Committee on Science and Technology. U.S. House of Representatives, Oct. 30, 31, 1979, pp. 677-678.

Participants had been sent a list of three questions to which NASA wished answers. These were:

1. What, if any, are the pertinent issues to the aeronautical community?
2. Assuming the above discussions identify issues of substantial concern - is there hard information or knowledge available to eliminate or resolve the problem?
3. For those issues where there is a need for additional information - what current research methods and approaches will provide the needed information?

In preparation for the workshop the participants were also sent two documents.

1. The ASRS draft report entitled "Fatigue and Associated Performance Decrements in Air Transport Operations - An Aviation Safety Reporting System Study" (Contract No. NAS2-10060) by E. Gene Lyman and Capt. Harry W. Orlady, July 28, 1980.
2. The report entitled "Effects of Circadian Rhythm Phase Alteration on Physiological and Psychological Variables: Implications to Pilot Performance" (NCA2-675-005) by Daniel C. Holley, July 15, 1980.

These reports provided a bibliography relating to the subject, together with summaries of relevant literature.

The participants were divided into three committees each consisting, insofar as possible, of scientists, pilots, and management flight operations personnel. A workshop member from NASA was assigned to each committee, and acted primarily as a moderator.

Following the statement of the problem by the Chairman, Dr. Sharp, each non-NASA participant was asked to present his personal position as it related to the problems. The workshop then separated into the three individual committees to consider the first question. A plenary session followed in which each committee presented its statement. General discussion of these statements ensued. The remaining questions were handled similarly. The meeting closed with a personal statement by each of the non-NASA participants on how he viewed the three days of proceedings.

As is inevitable when such diverse expertise is represented in a single room the discussions were wide-ranging, and often exceeded the scope suggested by the three original questions. Initially, the participants seemed unsure of what was required of them, but as discussion ensued they became more enthusiastic.

The reports of the individual committees have been coalesced to reflect the thinking of the group, and will now be presented. As has been stated, many concerns and interests were expressed during the discussions, and the original questions were expanded upon. These concerns and interests have been noted where relevant. There was general agreement on all of the issues. While unanimity was not attained, it is fair to say that the major differences of opinion concerned the severity of the problem, and the approach that should be taken to address the problem.

STATEMENT RELATIVE TO QUESTION 1

"What, if any, are the pertinent issues to the aeronautical community?"

The initial statements made by the participants indicated that most did not perceive a major problem relating to pilot fatigue or to circadian desynchronosis as factors in air safety. As the participants received additional information from their colleagues, these views began to change, at first imperceptibly, so that by the end of the discussion of this question there was general agreement that a problem might exist. There were two major hurdles.

The use of the terms "pilot fatigue" or "fatigue" were troublesome to many, particularly those from the biomedical research community. While it was recognized that fatigue is something that can be understood by all, Classical Physiology views fatigue from the standpoint of muscular fatigue and has so studied it. Since there is no evidence that the mind becomes fatigued the term "pilot fatigue" was perceived to be of limited usefulness. Further, pilot fatigue can at present be assessed only in subjective fashion, and sleepiness and lowered arousal, etc. can be confused with fatigue. As discussion proceeded during the course of the workshop, the participants became more comfortable with the concept of "performance decrement" of pilots, as such degradation can be studied more readily than subjective fatigue and can be quantified. Thus, questions regarding the effects of fatigue could not be answered while those regarding performance could.

The second hurdle was that, to some, it was neither fair nor correct to imply that pilot fatigue (or pilot performance degradation) was a cause of accidents, since the number of airline accidents is

relatively small. It was generally conceded that such performance degradation from whatever cause could lead to an increase in the probability of aircrew errors; and, also that as the error rate increased so did the probability, however small, of an accident. The recognition that these correlations are statistical quantities rather than absolutes did much to eliminate differences of opinion, and shifted the focus to the reduction of errors. There was no disagreement whatsoever that error reduction could probably lead to statistically increased air safety.

Question 1 was answered in the affirmative, that there is a problem, that there are issues here which are indeed pertinent to the aeronautical community. Disagreement existed as to the extent of the problem.

It was agreed that extensive literature already exists which provides much evidence that fatigue is increased (or performance degraded) in association with:

1. Sleep loss or deprivation and alterations of habitual sleep/wake cycles.
2. Circadian desynchronization associated with time-zone changes and irregularity of work/rest cycles.
3. Long duty hours.
4. Other human factors such as:
  - a. Long periods of low activity and lowered sensory input.
  - b. Letdown/relaxation/boredom.

- c. Less than optimal nutrition.
- d. Use of alcohol or drugs or other non-nutritive substances used to counteract fatigue and sleep difficulty.

Obviously, many of these factors are interrelated. Night flying or time-zone changes induce phase shifts of the circadian system and result in increased sleepiness and alterations of mood.

Functions altered by disturbances in biological rhythms include sleepiness, vigilance, short-term memory, task sequencing, mood, etc.

Quantification or identification of fatigue has heretofore been based on subjective measures, and fatigue cannot be readily distinguished from other sources of error, e.g., lowered arousal.

The concept of pilot-capacity/demand-on-the-pilot provides a model for estimation of the margin of safety. Pilot capacity is diminished by the factors enumerated above while demand may be constant or may increase, thus reducing the margin of safety. What cannot be stated clearly is the extent of reduction of pilot capacity (performance) by any of these factors, nor, perhaps more importantly, is much known relative to their interactions, i.e., whether they are additive or synergistic. What was agreed upon was that any of these factors or interactions could reduce performance capacity and that when the demand on the pilot exceeded his capacity the probability of an error increased.

It was apparent that the aviation system has been designed so that performance decrements lead infrequently to accidents. However, since such decrements may lead to errors and errors may lead to accidents, efforts to minimize the likelihood of decrements should be undertaken. Some specific remedies may already exist, including more optimal scheduling, improved nutrition, and by the education of pilots as to the problems they are likely to encounter, how to recognize them, and the provision of countermeasures.

The subject of individual differences or variation among pilots was much discussed. It is known that people differ as to their tolerance for irregular work/rest schedules and that some are incapable of continued shift work. It was suggested that methods that predict whether an individual could tolerate shift work would be quite useful. Some, but not enough, information is already at hand.

A contributing factor to the difficulties in identifying the problem is the lack of appropriate methodologies for studies of accidents in which fatigue or circadian desynchronization may have been a factor. Accident investigators typically have not been trained in human factors or psychology. These deficiencies may be remedied by the preparation of appropriate live operations survey/questionnaire materials.

STATEMENT RELATIVE TO QUESTION 2

"Assuming the above discussions identify issues of substantial concern--is there hard information or knowledge available to eliminate or to resolve the problem?"



As mentioned, there are extensive data already in existence. With regard to fatigue as a factor in unwanted occurrences in air operations there were at least 10 sources of data identified, either actual or potential:

1. Anecdotal information.
2. Captain's irregularity reports.
3. Company interviews regarding irregularities.
4. The ASRS data base.
5. Solicited information through the ASRS mechanism.
6. Derivative information from other transportation modes and basic research.
7. Military, particularly Military Airlift Command.
8. The ALPA Fatigue Survey.
9. The Iberian pilot study, nearing completion.
10. Requested pilot feedback.

Additional occurrence reports are needed as well as information on the relationship of fatigue factors (duty, recreation, rest, sleep, diet, activity, drugs) to accidents. While time-zone effects on performance are known, not much is known of the effects of low activity levels. It is easier to study the effects of these factors on performance decrement than on fatigue, per se.

Further, extensive data exist with respect to performance under various work/rest schedules. Truckers, railroad engineers, ship crews, as well as shift workers have been studied to various degrees. Research on various physiological functions which exhibit circadian rhythms has been done, and, in particular on what happens when these superimposed daily patterns are altered.

While data exist on the effects on performance of a single 16- or 18-hour tour of duty, less is known about a pilot's ability to perform throughout several such tours of duty on successive days.

There is evidence that performance is adequate following time-zone changes which do not result in sleep loss, thus re-emphasizing the role of sleep loss in reduction of performance capacity. If sleep loss is inevitable, appropriate sleep time (relative to the biological clock) should be allowed before the next scheduled flight. Recovery time should take into account the amount of sleep lost, based on known data.

The pilot should also be made aware of the cumulative effect on his performance capacity of partial sleep loss, and scheduling should be made so that partial sleep loss is minimized. Each pilot should be made aware of the potential effects of sleep loss on his performance, namely on visual motor potential skills, his ability to receive information, attention span, short term memory lapses, vigilance, etc.

What is not known are the effects on cockpit performance of losses of particular amounts and periods of sleep nor the best strategies for scheduling sleep outside of normal sleep time.

While there are data relative to circadian effects on psychomotor performance, there are few or no similar data on complex decision making performance, nor on social cooperation and interactions.

Pilots should practice good nutrition but it cannot, at this time, be stated what specific foods or diets should be recommended to mitigate performance decrements in aircraft operations.

The question of age and rate of adaptation was discussed. There is evidence from basic research that subjects over the age of 40 developed

desynchronosis in temporal isolation rhythms. There is also evidence that in free running (extended periods without time indications) there are few age differences in rhythm synchronization/desynchronization, but that there are differences in sleep patterns. There have been no good phase shift studies with respect to age. It is also possible that older people may show less of a performance decrement than younger people with respect to sleep loss because they have learned to pace themselves.

STATEMENT RELATIVE TO QUESTION 3

"For those issues where there is a need for additional information--what current research methods and approaches will provide the needed information?"

Once again, it was stressed that there is a great deal of data available already, and that, while not all of it is directly applicable, much of it may be. This information has not been used adequately to date. There was some concern as to whether data that may be collected pursuant to research projects recommended by the participants would, in fact, be used to improve regulations, or in any other way. Also, there is a fairly serious information gap between the scientific literature and the operational people who might be able to use it, and another between the scientific community and people such as passengers who might make use of information provided by scientists.

There was wide agreement that the information available needs to be digested or translated and disseminated to those who stood in need of it: pilots, air traffic controllers, cabin crew, members of regulatory bodies and the public.

During the discussions results from research, e.g., on neurotransmitters, nutrition, feeding schedules, etc., were applied to the problem at hand. These data were derived from animal studies as well as basic human studies. Other data discussed were obtained from ground-based or simulator studies. There was a pervasive feeling, however, that the hard information being sought would be obtained only from operational studies, i.e., those conducted in the cockpit environment. In order to design operational studies a number of preliminary studies need to be carried out. One such study, for example, was proposed to be conducted for 30 days of the sleep/wake cycles within an extended mission environment. Data would be collected from approximately 50 pilots. Measurements would be made at bedtime, sleep onset, time of awakening, and arising time for each 24-hour period for each pilot. These data would be correlated with flight times and duty times. Additional information would be obtained regarding subjective mood, pilot perceptions, and mission requirements. If feasible, data would also be collected on such factors as meals and alcohol consumption.

Another analogous study would be an operational test (conducted in airline cockpits) with the goal of gathering objective data on sleep disturbance and sleep deprivation, where such data would be obtained using electroencephalographic methods.

With the possible exception of improved methodologies for collecting questionnaire/survey data and, perhaps, the development

of novel psychomotor and complex decision-making tasks to measure performance decrements, adequate research methodologies appear to be in place. Devices to continuously monitor heart rate, body temperature, and activity, which do not interfere with the pilot's normal daily activities, already exist. Properly used, such devices would provide a wealth of information on these biological rhythms and on their relationship to the rhythmicity of sleep.

Recognition of individual differences with respect to tolerance of altered sleep/wake cycles and rates of readaptation led to the suggestion that the two extremes of the population be studied. Are there coping mechanisms used by some, the successful adaptees, and not by others? Do the extremes differ in lifestyles?

Information furnished by the studies broadly outlined above would be vital in the design of full-fledged, and perhaps definitive, operational cockpit studies. It was also suggested that simulator studies could be helpful. Discussions centered around two as representative. One where flight crews returning from "fatigue" inducing flights would be placed in their company's training simulator for an additional "flight leg" to observe performance. This performance would then be compared to performance in simulator flights when the crews were well rested. A suggestion was made that the first of any such studies utilize crews returning from the most difficult tours of duty. The other model suggested for simulator studies focused on a systematic examination of sleep/wake histories of flight crews representative of actual live conditions. Here ground based scenarios

such as those used by H. P. Ruffell Smith\* were recommended. It was generally believed that before these simulator studies or other laboratory research were to be undertaken a clearer understanding of the operational flightdeck environment and its associated difficulties was necessary. The operational flight surveys should be the first step.

There was much discussion on selection of pilots for the flight studies. The use of volunteers was somewhat suspect in that they might represent a biased sample. Pilots' groups receive numerous requests for pilot participation in studies, the aims of which frequently do not seem relevant to the needs of the groups' members, and their organizations have, therefore, turned away many such requests. The pilot and airline participants felt that the aims of the studies outlined above would be supported by their organizations and strong pilot participation could be expected.

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\*H.P. Ruffell Smith, A Simulator Study of the Interaction of Pilot Workload with Errors, Vigilance, and Decisions, NASA TM 78482, Jan. 1979.

PILOT FATIGUE AND CIRCADIAN DESYNCHRONOSIS WORKSHOP

August 26 - 28, 1980

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1. Report No. NASA TM 81275		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle  Pilot Fatigue and Circadian Desynchronosis*				5. Report Date	
				6. Performing Organization Code	
7. Author(s)				8. Performing Organization Report No.  A-8528	
9. Performing Organization Name and Address  Ames Research Center, NASA Moffett Field, California 94035				10. Work Unit No.  505-35-21	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address  National Aeronautics and Space Administration Washington, D.C. 20546				13. Type of Report and Period Covered  Technical Memorandum	
				14. Sponsoring Agency Code	
15. Supplementary Notes  *Report of a Workshop held in San Francisco, California, on August 26-28, 1980					
16. Abstract  A workshop on pilot fatigue and circadian desynchronosis was sponsored by the Man-Vehicle Systems Research Division at Ames Research Center in August 1980. The workshop was designed to elicit the opinions of experts with regard to whether circadian desynchronosis is a significant problem in air transport flying, the magnitude of the problem, and possible ways to approach it from a research viewpoint. Workshop participants included scientists from universities, military and other government laboratories, and aviation operations specialists from the airline industry and air carrier pilots.  It was concluded that there is a safety problem, of uncertain magnitude, due to transmeridian flying and a potential problem due to fatigue in association with various factors found in air transport operations. Much information is already available in the scientific literature, but there is a clear need to "translate" this information into terms meaningful to line flight personnel. The participants agreed on a need for better, hopefully objective data regarding the sleep, activity, and other pertinent factors from pilots flying a variety of demanding schedules. Simulation studies of flight crew performance should be utilized to determine the degree of fatigue induced by demanding schedules. Further simulation studies should be performed to delineate more precisely the factors responsible for performance decrements in flight and to test solutions proposed to resolve problems induced by fatigue and desynchronosis.					
17. Key Words (Suggested by Author(s))  Fatigue Pilot fatigue Crew fatigue Performance Circadian Dysrhythmia				18. Distribution Statement  Unlimited   STAR Category - 03	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 17	
				22. Price* \$4.00	